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PRODUCT INNOVATION AS A STATIC GAME OF INCOMPLETE INFORMATION IN A NON-BAYESIAN ENVIRONMENT

by

Guy Wolf (wlfguy001)

A minor dissertation submitted in *partial fulfillment* of the requirements for the award of the degree of Master of Social Sciences in Economics

Department of Economics

Faculty of the Humanities

University of Cape Town

2001

COMPULSORY DECLARATION

This work has not been previously submitted in whole, or in part, for the award of any degree. It is my own work. Each significant contribution to, and quotation in, this dissertation from the work, or works, of other people has been attributed, and has been cited and referred.

Signature Signed by candidate Date 12/01/01

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Acknowledgements

I would like to thank Professor Don Ross of the University of Cape Town for his insightful comments and supervision during the completion of this paper. I would also like to thank the University of Cape Town for the award of a Research Associateship that assisted in the completion of this paper.

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Introduction

The apparent failure of incumbent firms to produce radical innovations is one that continues to provoke significant debate in the economic literature. This phenomenon, termed the "Incumbent's Curse" by Chandy and Tellis (2000, p.2) receives significant support. Rosenbloom and Christensen (1994, p.655) go as far as to say that this is one of the "stylised facts" in the innovation literature. The concept of incumbent failure to innovate receives support both in theoretic modelling (e.g. Ghemawat 1991, Reinganum, 1983) and in empirical case studies (e.g. Christensen 1993, Henderson and Clark 1990). Chandy and Tellis (2000) rightly point out however that such literature has focused on industries in which there is such incumbent inertia. There are well documented examples of leadership in a high profile industry changing with new product innovations, e.g. typewriters, computer disks. However, much of the literature has been focused on very specialised industries such as photolithographic aligners (Henderson and Clark 1990) and private branch exchanges (Ghemawat 1991). Those opposing the idea of the Incumbent's Curse also have focused on particular industries. Chandy and Tellis (2000) used a large sample (64) of products in the consumer durables and office product categories in an empirical study. They showed that post-1945, the majority of radical product innovations have come from large firms and incumbents, thus raising the question of whether the incumbent's curse really can be regarded as a general feature of incumbency.

Clearly the question is one of importance from a policy making perspective. Schumpeter (1942) claimed that monopoly was a necessary evil in order to promote research and development. The incumbent's curse clearly refutes this view. The question of who has the greater incentive to innovate, incumbent or entrant, is key in determining competition policy. It is also clear, however, from the literature that there is no general solution to this question. Some industries have been characterised by a cycle of entrant innovation, subsequent leadership and incumbency, and finally usurpation by a new innovating entrant. This is the story told by much of the literature mentioned above. However there are also examples of incumbent firms

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producing radical new innovations: General Electric (fluorescent lamps), Philips (compact disc players) and Seiko (analogue quartz watches). Therefore, any attempt to produce a model in an attempt to understand the driving factors of product innovation must be flexible enough to respond to the characteristics of different industries.

That then is the challenge that this paper sets itself, to produce a model of product innovation, in an incumbent – entrant scenario, which removes the vast majority of the assumptions made in most models which can be so overpowering as to pre-determine the result of the analysis. Using such a model, we may test the sensitivity of any assumptions made as well as gaining an insight as to what are the drivers behind innovation for an industry. We should then come to a better understanding as to why different industries exhibit different research and development patterns.

Sutton (1998) makes the point that the wide discrepancy of equilibria derived from the literature comes not only from industry specific factors, but also the way in which the model is set up. There are a variety of ways in which one can set up a model of product innovation. Do the players act simultaneously? Are decisions to set up R&D programs irreversible? Is it a "winner takes all" patent race? The answers to these questions would clearly determine the way in which the model is set up and therefore the Nash equilibria derived from the model. This paper began as reflections on the model set up by Ghemawat (1991) and so shall use this framework for my analysis. That is to say, the game shall be set up as found in the extensive form shown in Figures 1 and 2. This shows the players acting simultaneously and irreversibly, incurring a fixed cost of attempting innovation with an attached probability of succeeding. There is a possibility of a duopoly in the new product market.

The model shall be built in two phases. The first stage, the standard model, includes a number of simplifying assumptions. That is, any innovation is drastic, implying complete cannibalisation of the old product market. Also the new product market is worth exactly the same as the old market. Finally, in the case of duopoly, this is perfectly collusive. It shall be shown that a model set up in this way restricts the possible Nash equilibria to exclude the possibility of the incumbent firm having greater incentive to innovate than the entrant does.

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We shall then move on to expand the model into the variable form, introducing new variables for cannibalisation, spillovers[1], and incumbent advantage and ferocity of competition in a duopoly. The purpose of doing this is that by introducing variables in place of assumptions we can examine the sensitivity of the model to the assumptions made on the value of these variables. Here, we shall see how assumptions of Bertrand price competition in the case of duopoly and no spillovers in the secondary product market combined with a viability condition can lead to a restriction of the model to a single Nash equilibrium.

Even after this there are assumptions made regarding the information sets and rationality of players that must be tested. The importance of modelling the game as one of incomplete information is an important one, as is made clear in the paper. The impact of information on the result of the analysis turns out to be significant. It is appropriate that we should investigate the impact of an assumption of common knowledge as it is an assumption typically made in game theoretic analysis that would rightly attract criticism from business practitioners and policy-makers. The philosophy behind this paper is to move as far away as possible from the unrealistic assumptions often made in order to simplify analysis and to obtain, in so far as it is possible, a fuller understanding of the drivers of innovation in situations that are more complex than those typically represented in stylised models.

The avenue opened up by the investigation into a game of incomplete information using Bayesian players has been pre-empted by the choice to investigate a static game. Clearly, in a game where the players make decisions simultaneously, there can be no scope for Bayesian updating. But the aim of this analysis is to clear a path for further research. Such research will certainly include looking at a dynamic game using conditional probabilities. But before such research can take place we must investigate thoroughly a static game of innovation and see what, if anything, can be salvaged from such a model and taken on into the dynamic settings.

1 Spillovers are defined as the degree of expansion of the market that will arise from innovation.

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Building the model

Standard model

We assume two firms, the incumbent I which holds a pre-innovation monopoly, and the potential entrant, E which we could assume to be the composite of all potential entrants. The cost of research, c is fixed, and the probability of success at innovation is p. Thus we could say that the firm can pay c for a p chance of successfully innovating. We also assume that p and c are the same for both the incumbent firm and the potential entrant. The initial market is worth x in profit to a monopolist. However, any innovation is drastic. That is, if an innovation occurs, it reduces the value of the earlier market to 0 and the new market becomes worth x. A typical example would be computer software, where an updated version completely supercedes the old version without necessarily increasing the overall value of the market. This combines the no spillovers assumption[2] with an assumption regarding complete cannibalisation of the initial market. If both firms successfully innovate we assume that a duopoly would be perfectly collusive and that each firm would make half of the monopoly profit. Both firms choose simultaneously whether to attempt innovation and all information about the variables is common knowledge between the firms.

The respective choices of the incumbent and entrant result in the game arriving at one of nodes 1 to 4 on the game tree of Figure 1. Nature then determines which, if any, of the firms are successful if they have attempted innovation. As each firm will not know the end node of the game but are aware of the probabilities involved, we can calculate the expected payoffs to each firm at each node.

2 By this we mean that the value of the new product market is exactly the same as the old one.

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***Node 1*:**

Expected payoff to Incumbent:

$$E(I_1) = p^2\left(\frac{x}{2} - c\right) + p(1-p)(x-c) + p(1-p)(-c) + (1-p)^2(x-c)$$
$$= \frac{p^2 x}{2} - px + x - c$$

Expected payoff to Entrant:

$$E(E_1) = p^2\left(\frac{x}{2} - c\right) + p(1-p)(-c) + p(1-p)(x-c) + (1-p)^2(-c)$$
$$= px - \frac{p^2 x}{2} - c$$

Node 2:

Expected payoff to Incumbent:

$$E(I_2) = p(x-c) + (1-p)(x-c)$$
$$= x - c$$

Expected payoff to Entrant:

$$E(E_2) = 0$$

Node 3:

Expected payoff to Incumbent:

$$E(I_3) = p(0) + (1-p)(x)$$
$$= x - px$$

Expected payoff to Entrant:

$$E(E_3) = p(x-c) + (1-p)(-c)$$
$$= px - c$$

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Node 4:

Expected payoff to Incumbent:

$$E(I_4) = x$$

Expected payoff to Entrant:

$$E(E_4) = 0$$

The choice of the incumbent firm will naturally be dependent on its view of the choice of the potential entrant. Clearly it would prefer to be at Node 4 above all others. The potential entrant has a dominant strategy not to attempt innovation if $px - c < 0$. If this is the case then the Nash equilibrium would be reached at node 4.

The potential entrant would only attempt innovation if $px - c \geq 0$. If the incumbent firm knows this then it then needs to establish whether $px - \frac{p^2x}{2} - c \geq 0$. If this is the case then attempting to innovate is a dominant strategy for the potential entrant. Therefore the choice for the incumbent depends on the payoffs at nodes 1 and 3. It would only choose to attempt to innovate if $\frac{p^2x}{2} - px + x - c \geq x - px$ which would lead to a Nash equilibrium at node 1, Otherwise, we have a Nash equilibrium at node 3.

If however for the entrant, $px - \frac{p^2x}{2} - c < 0$ and $px - c \geq 0$, then it would like to choose to attempt innovation only when the incumbent does not and vice versa. In other words its payoffs at nodes 2 and 3 are higher than at nodes 1 and 4.

We can see this by holding the position of the incumbent firm fixed and examining the choice of the potential entrant. If we take the opposite position and hold the decision of the potential entrant fixed, we can see that if the potential entrant chooses not to attempt innovation then the incumbent firm would choose to match this strategy as then it would be at node 4, its highest payoff. If the choice of the potential entrant

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was to attempt innovation then the choice of the incumbent would depend on whether it had a higher payoff at node 3 than node 1.

This being so the incumbent would have a dominant strategy not to attempt innovation. This would occur if $x - px > \frac{p^2 x}{2} - px + x - c$ which implies that $\frac{p^2 x}{2} - c < 0$. Knowing this, the potential entrant would choose to innovate as it receives a better payoff by doing so and a Nash equilibrium is reached at node 3.

We may ask what would happen if the incumbent firm faced a higher payoff at node 1 than node 3. This is actually not possible given the conditions we have set out earlier, namely, $px - c \geq 0$ and $px - \frac{p^2 x}{2} - c < 0$. If the payoff at node 1 was higher than at node 3, this would mean that $x - px < \frac{p^2 x}{2} - px + x - c$ which implies that $\frac{p^2 x}{2} - c > 0$. However, this contradicts the earlier inequalities. This is because $\frac{p^2 x}{2}$ can never be higher than one half of px and thus for $px - \frac{p^2 x}{2} - c < 0$, $c > \frac{p^2 x}{2}$ which is not consistent with node 1 delivering a higher payoff to the incumbent.

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Therefore we can establish the following summary:

- If $px - c < 0$, then the Nash equilibrium is node 4. This is because the potential entrant has a dominant strategy to not attempt to innovate. Knowing this the incumbent also chooses not to innovate.
- If $px - c \geq 0$, $px - \frac{p^2 x}{2} - c \geq 0$ and $\frac{p^2 x}{2} - px + x - c \geq x - px$ then the Nash equilibrium is at node 1. This is because the potential entrant has a dominant strategy to attempt to innovate. Knowing this the incumbent also chooses to innovate.

- If $px - c \geq 0$, $px - \frac{p^2 x}{2} - c \geq 0$ and $\frac{p^2 x}{2} - px + x - c < x - px$ then the Nash equilibrium is at node 3. This is because although the potential entrant still has a dominant strategy to attempt to innovate, the incumbent now chooses not to innovate.

- In the case where $px - c \geq 0$ and $px - \frac{p^2 x}{2} - c < 0$, the Nash equilibrium is also at node 3. The potential entrant does not have a dominant strategy but from the two inequalities it follows that $\frac{p^2 x}{2} - c > 0$ which implies that $\frac{p^2 x}{2} - px + x - c < x - px$. This means that the incumbent firm has a dominant strategy to not attempt to innovate. Knowing this, the potential entrant chooses to innovate.

There are no other possible situations within the context of this model and so we can conclude that mixed strategies are never necessary nor is node 2 ever reached. As discussed earlier, this result stems from the constraints we have placed on the model. The assumptions made at the start of the model determine the outcome. But this has not been a futile exercise. We now have a basis from which we can begin to test the sensitivity of the model to specific assumptions. Clearly we would expect a number of situations in which there would be a mixed strategy Nash Equilibrium and this becomes apparent as we develop the model. In order for the model to be useful in terms of testing the sensitivity of assumptions it is necessary to introduce new variables into the model in place of the assumptions made earlier. Later in this paper we shall see how the result derived from this restrictive model is replicated in a less restrictive model which assumes common knowledge and rationality.

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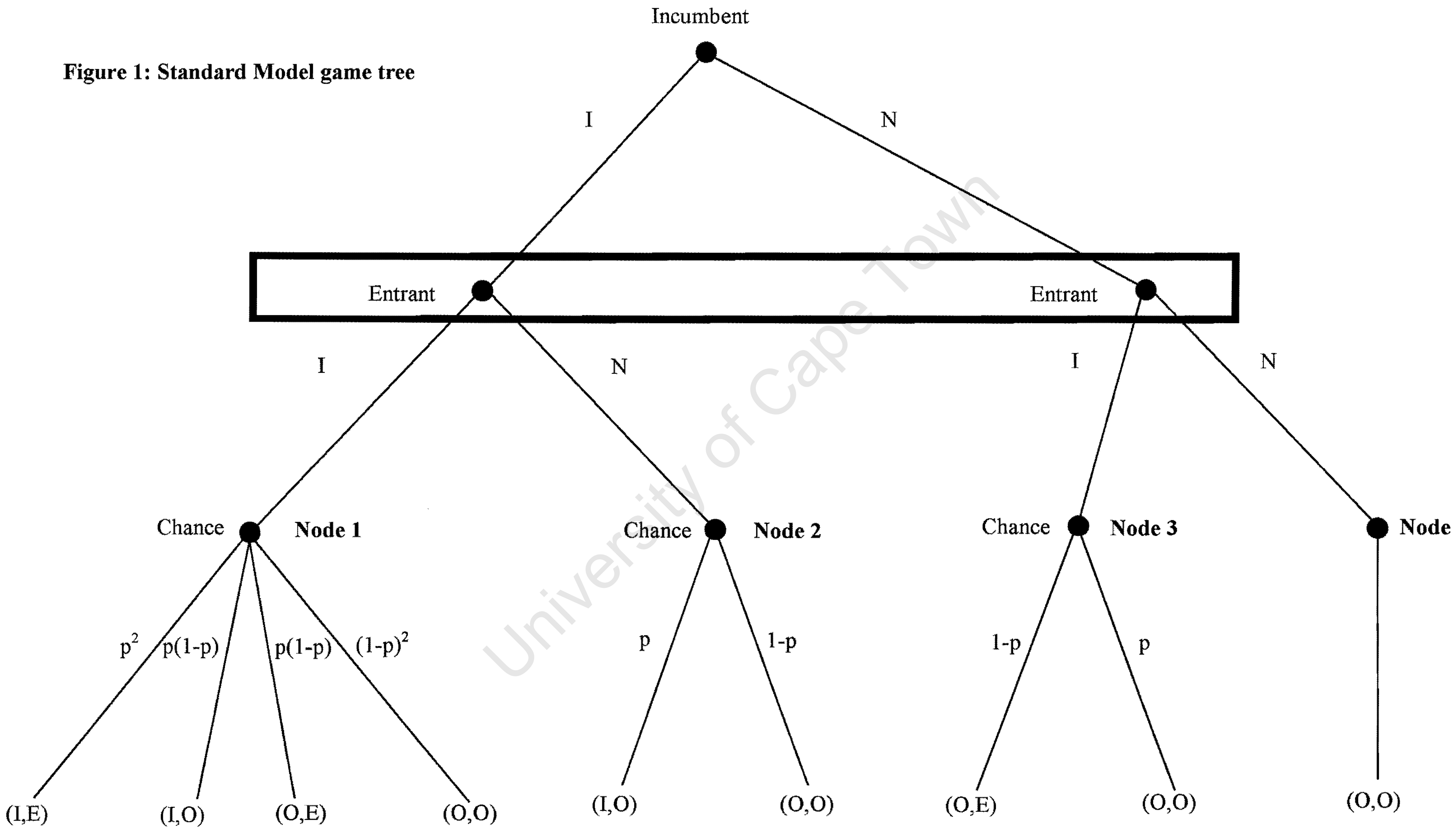
Figure 1: Standard Model game tree



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Variable model assuming common knowledge and risk-neutrality

We shall now adapt the model in order to test the significance of some of the assumptions we have made. Two of the variables from the previous model can remain, namely, x and c. We can remove the assumption about each firm having the same probability of succeeding at innovation by introducing two new variables in place of p, namely p_1, the probability that the incumbent will succeed, and p_2, the probability that the entrant will succeed.

We can also introduce two new variables that only affect the model if an attempt at innovation is successful. A cannibalisation variable, b, replaces the assumption that the old market was completely cannibalised by the new product. Now we can say that only the proportion b is cannibalised and $(1-b)$ remains. We also assumed that there were no spillovers from innovation. That is to say, that the size of the new market was precisely the same as the old market in terms of profit. We can remove this assumption by introducing the variable s which is the size factor of the new market to the old market. If there are positive spillovers from innovation the value of s will be greater than 1. The variables b and s are combined so that, given the initial market value of x, the value of the market for the new product to a monopolist will be bsx.

The other assumptions made were about the collusive nature of a duopoly in the new market and about the market share between the two firms. We can remove the assumption of duopoly profit being equal to monopoly profit by introducing a variable d which is the size factor of total profit under a duopoly to monopoly profit. Therefore, under a perfectly collusive duopoly, d is equal to 1. If fierce price competition were to occur leading to the Bertrand outcome, d would be equal to 0. We can also introduce a final variable, m, which is the market share of the incumbent firm in the new product market if a duopoly occurs. Previously we had assumed that the two firms would share the new market equally, i.e. that m was 50%. The market share of the entrant therefore is now $(1-m)$.

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The new game tree in Figure 2 results in the same four nodes being attainable by the respective actions of the incumbent and entrant firms. Nature again chooses the final outcome and hence we can calculate the expected payoffs to each firm at each node.

Node 1:

$$E[I_1] = p_1p_2(sbdmx - c + x(1-b)) + p_1(1-p_2)(sbx - c + x(1-b))$$
$$+ p_2(1-p_1)(-c + x(1-b)) + (1-p_1)(1-p_2)(x-c)$$
$$= xb((p_1p_2(sdm - s + 1)) + (p_1s - p_1 - p_2)) + x - c$$

$$E[E_1] = p_1p_2(sbd(1-m)x - c) + p_1(1-p_2)(-c) + p_2(1-p_1)(sbx - c)$$
$$+ (1-p_1)(1-p_2)(-c)$$
$$= p_1p_2sbd(1-m)x + sbxp_2(1-p_1) - c$$

Node 2:

$$E[I_2] = p_1(sbx - c + x(1-b)) + (1-p_1)(x-c)$$
$$= p_1sx - p_1x + x - c$$

$$E[E_2] = 0$$

Node 3:

$$E[I_3] = p_2(x(1-b)) + (1-p_2)(x)$$
$$= x - p_2bx$$

$$E[E_3] = p_2(sbx - c) + (1-p_2)(-c)$$
$$= p_2sbx - c$$

Node 4:

$$E(I_4) = x$$

$$E(E_4) = 0$$

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Through calculating expected payoffs at each node, the incumbent and the potential entrant can determine whether either of them have a dominant strategy. If this is the case then a Nash equilibrium is reached at one of the four nodes before nature decides the final outcome. However, unlike the stage 1 model, there can be occasions in which mixed strategies are necessary. If this is the case then the incumbent firm will choose to innovate with probability P_I^I and the entrant will choose to innovate with probability P_E^I where the probabilities are given by:

$$P_I^I = \frac{-E[E_3]}{E[E_1]-E[E_3]}$$

$$P_E^I = \frac{E[I_4]-E[I_2]}{E[I_1]-E[I_2]-E[I_3]+E[I_4]}$$

This model can now form the basis for a sensitivity analysis tool. The methodology used to achieve this is a MS Excel™ spreadsheet that can run this innovation game for millions of different scenarios based on the variables we have defined. We will then be able to observe the effects that a different level of each variable has on the outcome of the game. The exact layout of the spreadsheet written to generate the outcome of these scenarios is to be found in the appendix.

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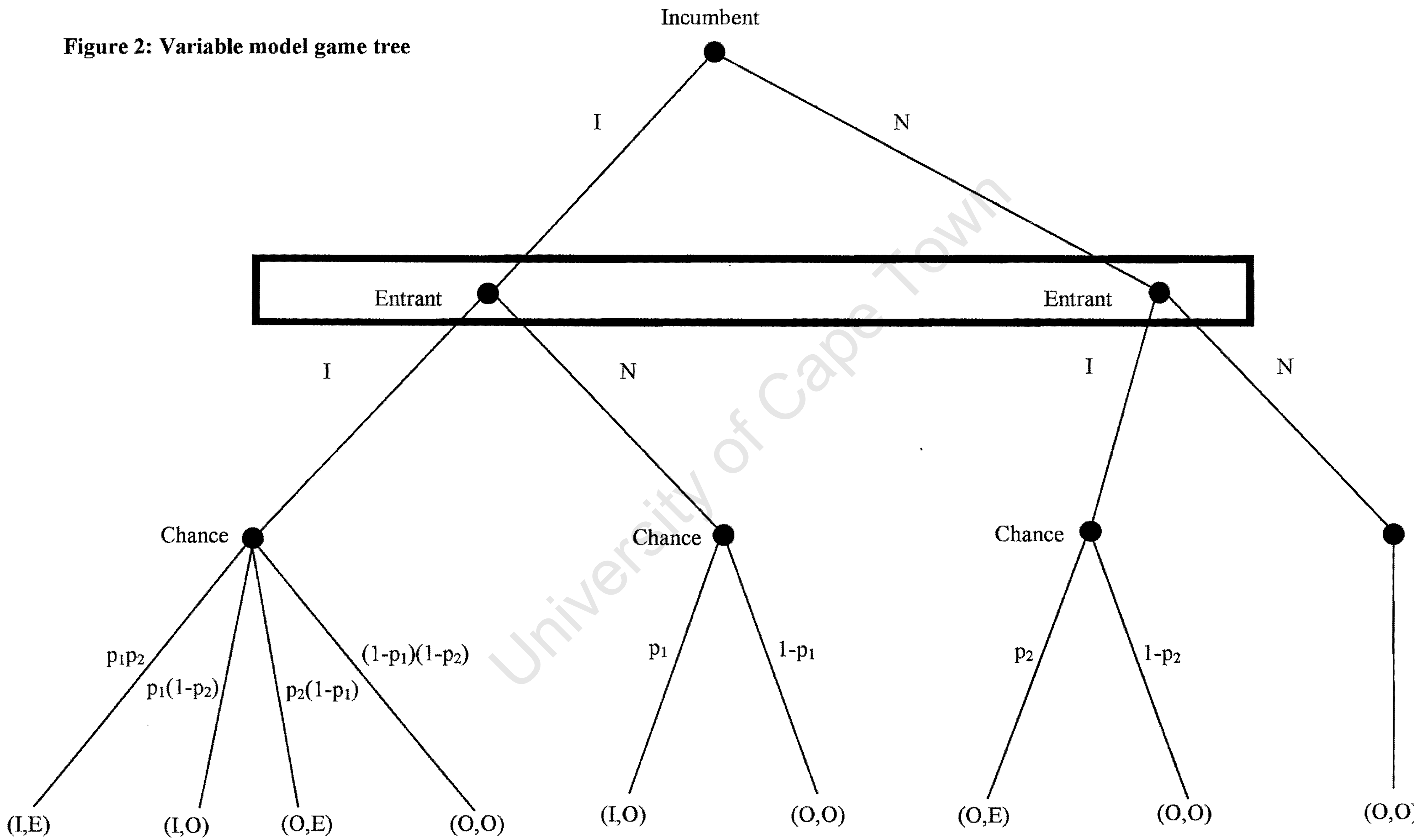
Figure 2: Variable model game tree



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Product innovation in a static game of complete information

Sensitivity of assumptions of market structure and presence of spillovers in the secondary product market

Now that we have a full model we can begin to test the sensitivity of the outcome of the game to some of these variables. Here we examine the implications of assumptions of Bertrand price competition and no spillovers in the secondary product market. We choose these assumptions as they are made in a model developed by Pankaj Ghemawat (1997). Thus this section is essentially a case study in analysing this particular model.

We shall also examine a further assumption made by Ghemawat, namely that the only possible situations in which the game can occur are those in which either player would attempt innovation if they were assured a monopoly in the new product market. That is to say the potential rewards from innovation are sufficient to mean that, if there was only one player, innovation would be attempted. We shall call this "Ghemawat's viability condition".

Ghemawat's model can be replicated to an extent by translating his assumptions into figures for the new variables introduced in the previous section. We are not fully replicating Ghemawat's model as we are not using conditional probabilities as he does, for reasons discussed previously. Rather we are using the assumptions he makes as ones that are typically to be found in game theoretic analysis and observing the effects that they would have on our model. He states that, 'any substitution between the two generations is one to one in quantities.'[3] In other words, he assumes no spillovers, thus we set s at 1.

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Ghemawat also assumes that only a portion of the market is cannibalised by the new product. The portion is determined by the difference in price between the two products. This is represented in our model by the variable *b* which can be set between 0% and 100%.

Ghemawat also states that if both firms enter the second-generation market, Bertrand price competition drives prices down to marginal cost.[4] This would usually be replicated by setting *d* equal to 0. However he also states that, 'the durable specific complements that customers acquired in using firm A's (the incumbent) first-generation products cannot be applied to either A's or B's second-generation products.'[5] This means that there is no advantage to the incumbent in the new market, therefore we again would normally set *m* at 50%. However, Ghemawat also assumes that if the incumbent firm were to succeed at innovation at the same time as the entrant, the incumbent would shelve the new product as the cannibalisation of the old market would be less severe. As there is no profit to be gained in the new market this is rational. Thus, in order to replicate these assumptions we must set *d* as 1 and *m* as 0%. That is to say, there are profits to be made in the duopoly scenario but the incumbent makes none of them.

Ghemawat's fixed costs of attempting innovation are given as *c* and we set p_1 equal to p_2 as the probabilities of the two firms succeeding at innovation are the same.[6] Given that we hold *x*, the size of the market, constant at 100, we can see that there are 3 variables to be considered, *p*, *c* and *b*. All of the others are held fixed.

For the analysis we shall set *b*, the cannibalisation variable at 100%, thus giving the incumbent the most incentive to innovate. The reason for this is that the traditional result of the analysis shows that the incumbent will not innovate. By setting *b* to 100% we are giving the incumbent the maximum possible incentive to innovate. If the result remains the same then this will demonstrate even more clearly how strong the assumptions are that are being made. If we then introduce Ghemawat's viability

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5 p.129
6 p.133

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conditions[7] we can see from Figure 3 that under 'viable' values of p and c (signified by V in Figure 3[8]), the game will always have a Nash Equilibrium at Node 3. Even when the cost of attempting to innovate is 0, the incumbent will still not attempt innovation as his expected payoff at node 1 will be the same as at node 3. Thus it has a weakly dominant strategy not to innovate.

This is clear by looking at the expected payoffs for the incumbent at the various nodes. As d is 0, there is no difference between sharing the new market and having it completely cannibalised by the entrant. Any decrease in the amount of the market to be cannibalised merely reduces the incentive to innovate still further for the incumbent. As there are no spillovers, node 2 can never be better than node 1 for the incumbent. Also, as d is 0, node 1 can never be better than node 3. Therefore the incumbent will never attempt innovation.

Also, for the entrant, there is a dominant strategy to attempt innovation, regardless of the values of c and p. This is because the entrant's expected payoffs at nodes 1 and 3 are always positive and thus a better option than staying out of the market. Therefore, if we were to assume these viability conditions, on top of the assumptions regarding spillovers and market structure, our model would be forced to produce the same outcome whatever the values of our variables.

For our analysis of the sensitivity of the model to the assumptions regarding spillovers and Bertrand price competition we shall reset M to 50%, assuming that neither firm has an advantage in the new market. This is not a restrictive assumption. It is simply that we have no information regarding the nature of the second prodcut market and thus should not assume an advantage to either player.

We must vary d, the variable that represents the ferocity of competition in the new market to observe the sensitivity of the model to the Bertrand assumption. In the

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7 p.133 , $\prod_A(E,O) - \prod_A(O,O) > \frac{F_A}{y}$,

$\prod_B((O,E) > \frac{F_B}{\min(z_1, z_2, z_3)}$

8 These tables are generated by the MS Excel spreadsheet that calculates the outcome of the game for the respective values. This demonstrates the sensitivity of the game to changes in the variables.

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same way we can vary values of s to observe the sensitivity of the model to the assumption of no spillovers. We set c to 0, a situation in which node 3 is reached and the incumbent firm is indifferent about attempting innovation, and examine the effects of varying s and d. We can see, from Figure 4, that these have a significant effect on the decision of the incumbent firm.

Obviously, the cost of attempting innovation would not be zero in reality. However, we know what the effect of a positive cost would be, namely that more profit would be required to justify incurring it. By setting it to zero we simply are removing its influence from the analysis and this allows us to see the effects of movements in s and d more clearly.

From Figure 4 we can see that in this situation, although the entrant has a dominant strategy to innovate, the strategy of the incumbent is sensitive to s and d. When the fixed costs of attempting innovation are zero, we can see than any positive spillovers whatsoever result in the incumbent attempting innovation, even if we continue to hold the assumption that profit in the duopoly market is zero.

Also if we maintain that there are no spillovers then the existence of any positive profit in the new product duopoly scenario is sufficient to lead the incumbent firm to attempt innovation. As the cost of attempting increases then the model naturally becomes less sensitive as the incumbent requires ever more incentive to attempt innovation.

This is a clear illustration of the importance of testing the significance of assumptions made in a game theoretic model. In this case the assumptions were powerful enough to ensure that the outcome of the game was fixed regardless of the level of the other variables in which the game took place.

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Figure 3 : Ghemawat's Viability Condition

P

C	0%	4%	8%	12%	16%	20%	24%	28%	32%	36%	40%	44%	48%	52%	56%	60%	64%	68%	72%	76%	80%	84%	88%	92%	96%	100%
0	-	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V
4	-	-	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V
8	-	-	-	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V
12	-	-	-	-	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V
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24	-	-	-	-	-	-	-	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V
28	-	-	-	-	-	-	-	-	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V
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64	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	V	V	V	V	V	V	V	V	V
68	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	V	V	V	V	V	V	V	V
72	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	V	V	V	V	V	V	V
76	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	V	V	V	V	V	V
80	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	V	V	V	V	V
84	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	V	V	V	V
88	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	V	V	V
92	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	V	V
96	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	V
100	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

P

C	0%	4%	8%	12%	16%	20%	24%	28%	32%	36%	40%	44%	48%	52%	56%	60%	64%	68%	72%	76%	80%	84%	88%	92%	96%	100%
0	4	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
4	4	4	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
8	4	4	4	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
12	4	4	4	4	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
16	4	4	4	4	4	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
20	4	4	4	4	4	4	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
24	4	4	4	4	4	4	4	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
28	4	4	4	4	4	4	4	4	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
32	4	4	4	4	4	4	4	4	4	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
36	4	4	4	4	4	4	4	4	4	4	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
40	4	4	4	4	4	4	4	4	4	4	4	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
44	4	4	4	4	4	4	4	4	4	4	4	4	3	3	3	3	3	3	3	3	3	3	3	3	3	3
48	4	4	4	4	4	4	4	4	4	4	4	4	4	3	3	3	3	3	3	3	3	3	3	3	3	3
52	4	4	4	4	4	4	4	4	4	4	4	4	4	4	3	3	3	3	3	3	3	3	3	3	3	3
56	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	3	3	3	3	3	3	3	3	3	3	3
60	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	3	3	3	3	3	3	3	3	3	3
64	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	3	3	3	3	3	3	3	3	3
68	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	3	3	3	3	3	3	3	3
72	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	3	3	3	3	3	3	3
76	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	3	3	3	3	3	3
80	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	3	3	3	3	3
84	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	3	3	3	3
88	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	3	3	3
92	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	3	3
96	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	3
100	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4

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Figure 4 : Sensitivity to market structure and spillovers

S

D

	0.80	0.82	0.84	0.86	0.88	0.90	0.92	0.94	0.96	0.98	1.00	1.02	1.04	1.06	1.08	1.10	1.12	1.14	1.16	1.18	1.20	1.22	1.24	1.26	1.28	1.30
0.000	3	3	3	3	3	3	3	3	3	3	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
0.025	3	3	3	3	3	3	3	3	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
0.050	3	3	3	3	3	3	3	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
0.075	3	3	3	3	3	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
0.100	3	3	3	3	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
0.125	3	3	3	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
0.150	3	3	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
0.175	3	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
0.200	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
0.225	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
0.250	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
0.275	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
0.300	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
0.325	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
0.350	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
0.375	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
0.400	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
0.425	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
0.450	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
0.475	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
0.500	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
0.525	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
0.550	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
0.575	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
0.600	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
0.625	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Figure 5: Summary of results of relaxation of assumptions

Assumptions made	Incumbent	Entrant	Possible Node N.E.
Viability Conditions, no spillovers, Bertrand price competition	Never attempts innovation	Always attempts innovation	3
Remove Viability condition	Never attempts innovation	Sometimes attempts innovation	3, 4
Also remove no spillovers and Bertrand assumptions	Sometimes attempts innovation	Sometimes attempts innovation	1, 2, 3, or 4

As we would expect, as the assumptions regarding the context in which the game is played are relaxed, the possible outcomes multiply.

Product Innovation in a static game of incomplete information

Significance of assumptions of common knowledge and risk-neutrality

In the previous section, we were able to remove the majority of any assumptions made in the standard model by replacing them with variables and we were then able to examine the effects of the various levels of these variables. However, that is not to say that no assumptions have been made. We have thus far made the assumption that all of the variables in the model are common knowledge between the players, as is the rationality of the players. The other assumption we have made is that the players are risk-neutral – that is, their utility functions are linear with the distribution of Mother Nature's acts. Now if the common knowledge assumptions hold, the risk-neutrality assumption is not significant. This is because each player can fully predict the decision of the other and hence the strategic decision is simply to maximise the expected payoff, given this decision. Attitude to risk under these conditions is irrelevant. All of the decisions lead to a lottery as the outcome. There is no opportunity to take a guaranteed payoff in place of a lottery which generates an equal expected payoff.

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If one of the common knowledge assumptions is relaxed (we shall see that it does not matter which), the assumption of risk-neutrality becomes more significant. This is because if the players cannot fully predict the decision of the other player, they must each consider the worst case scenario when the action of the other player serves to minimise their expected payoff. Which of the common knowledge assumptions that is relaxed is irrelevant. The key here is that each player cannot fully predict the action of the other player. If rationality is not common knowledge then there is the possibility that the other player will choose a dominated strategy. Similarly, if the values of the variables are not common knowledge then there is the possibility that the other player will calculate a different scenario and will thus choose what the player considers to be a dominated strategy whether rationality is common knowledge or not. Thus it only takes a very small degree of uncertainty to make the risk-neutrality assumption significant and, given the large number of variables in the model, it would seem that an assumption of common knowledge over the value of all the variables is highly optimistic.

We must then consider what the impact of removing the risk-neutrality assumption is. We are not referring to risk-neutrality or aversion in the traditional sense. The choice here is still between lotteries, there is no possibility of a guaranteed payoff. What we are trying to consider here is how players will react if there is the possibility that players might find themselves with a far worse lottery than their reasoning based on mutual knowledge of full rationality would predict for those reasons outlined earlier. A more sensible reflection of risk-averse players would be to consider what would occur if the players were each to play a strategy similar to a security strategy.[9] That is to say, they were to assume that the choice of the other player would minimise their payoff given their own decision.

We must clarify here the level of information available to each player. Neither player is aware of the strategy of the other player. Each player has the same information regarding the values of the variables, however they do not know what the other player believes them to be. Therefore they cannot predict the decision of the other player. Thus the strategic decision of each player now is to assume that whatever their decision, they will secure the worst possible expected payoff in the set of vectors consistent with that decision (not the worst possible result; this would be to assume that nature is also against them), and they must act to maximise their expected payoff, given this assumption. This is a re-iteration of the concept of a security strategy.

9 This is not literally a security strategy as the removal of the no spillovers assumption means that this is no longer a zero-sum game. However, the principle is the same. The players seek to protect themselves by maximising their minimum expected payoff.

Security strategies in product innovation

We have therefore determined that players, faced with conditions of uncertainty, shall base their strategic decision on the assumption that the other player will be trying to enter the new product market. The impact of using the security strategy in the product innovation game is significant in determining the relative incentives for innovation between the incumbent and the entrant. The question of who has the greater incentive to innovate is central to the concept of the Incumbent's Curse.

In calculating the respective incentives to innovate we simply use the formula 'what you get if you do minus what you get if you don't'. Clearly if you receive a higher expected payoff from attempting innovation than from not attempting, you will attempt innovation. In order to see the impact of risk aversion on innovation incentive we must compare the two different sets of incentives.

Rational players with complete information

Incumbent:
$$\begin{aligned}&[p(sbx - c + (1-b)x) + (1-p)(x-c)] - x\\ &= psbx - pbx - c\end{aligned}$$

Entrant:
$$\begin{aligned}&[p(sbx - c) + (1-p)(-c)] - 0\\ &= psbx - c\end{aligned}$$

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Therefore, looking at the players in isolation, the entrant will always have a greater incentive to innovate than the incumbent will by a factor of pbx. It is this result that drives the theory of the incumbent's curse. Although the incumbent may well have a positive incentive to innovate, the entrant will always have a greater incentive. From the point of view of our game theoretic model, this means that node 2, where the incumbent attempts and the entrant does not, can never be reached as this would imply that the incumbent had an incentive to innovate in a situation where the entrant did not. This was an impossible scenario under the assumptions of rationality and complete information.

Indeed this is a similar result to that derived from the standard model discussed earlier. This model contained only three variables, p,c and x, and carried some very restrictive assumptions. Within this model, reaching node 2 was also impossible. But even after removing the majority of these assumptions, we find that although this would be expected to free up the model to a large extent, the assumptions of common knowledge and complete information delivers the same result. That is, that Node 2 can never be reached.

If these assumptions are removed, players opt for a security strategy as previously discussed. This means that players assume that the other player will attempt innovation. Thus incentives are calculated by the expected payoffs obtained at the respective nodes of the game where the other player has attempted innovation. These are nodes 1 and 3 in the case of the incumbent and nodes 1 and 2 in the case of the entrant. This has profound effects on the incentives for innovation.

Risk-averse players with incomplete information

Incumbent:

$$(I_1 - I_3)$$
$$= p^2 smbdx + p^2 sbx + 2p^2 bx + psbx - pbx + p^2 c - p^2 x + px - c - p$$

Entrant:

$$(E_1 - E_2)$$
$$= p^2 sbdx - p^2 smbdx + psbx - p^2 sbx - c$$

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In this case the players consider that they will find themselves at an end node in which the other player is attempting innovation. As a result, in calculating incentive to innovate, they must decide between the lotteries to be found at the respective end nodes. In the case of the incumbent these are I_1 and I_3, and in the case of the entrant, E_1 and E_2. Clearly, under these conditions, it is not the case that the potential entrant will always have a greater incentive to innovate than the incumbent as we cannot say with certainty whether one incentive is larger than the other. Who will have the greater incentive will depend on the values of the respective variables that characterise the industry in question.

This means that we have finally broken free of the constraint on the model over the possibility that the incumbent may have a greater incentive to innovate that the entrant. We are not trying to pre-determine the outcome of the model here. Making a Nash Equilibrium at Node 2 possible is not prejudicing our investigation. It is the fact that, if possible Nash equilibria are closed off by our restrictive assumptions, we cannot with confidence proceed to an investigation of which variables drive innovation.

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Types of Innovation

We are therefore free to continue our investigation into the causes of innovation. We know that all Nash equilibria are potentially possible. Now the question must be what vectors of the set variables deliver which outcome. Now that we have identified the fact that the characteristics of the industry will determine the respective incentives of the players, and therefore potentially the resultant innovator, we must examine a range of scenarios which might be said to be reflective of the types of innovation observed.

Innovation is often split into two classes, radical and incremental. Radical innovation significantly changes the product and the consumption pattern of consumers. Incremental innovation has a markedly smaller effect on the product and therefore consumption behaviour. Henderson and Clark (1990, p.9) argue that "the characterisation of innovation as either incremental or radical is incomplete and misleading and does not account for the sometimes disastrous effects on industry incumbents of seemingly minor improvements in technological products." They refer to the concept of architectural innovation which can be defined as changing the "architecture of the product without changing its components." This concept is quite industry-specific in that it refers generally to products of a technological nature. However, Henderson and Clark claim that such a type of innovation offers another way for entrants to steal ahead of inert incumbent firms.

In terms of an investigation into the possible existence of an Incumbent's Curse however, this is of limited interest. If an innovation could be done easily and would cannibalise the old market significantly then firms would clearly go ahead and do it. Thus we would expect a Nash equilibrium of Node 1 in most cases of architectural innovation. It is possible that an incumbent would shelve such an innovation if they were successful, given low spillovers or high cannibalisation, but they would still attempt. The aim of this paper is to develop insights into the factors that drive innovation attempts. An investigation into situations that always lead to attempts would not be of interest.

Incremental innovation

We must ask, what are the features that one might expect to see when incremental innovation is being attempted? Given that incremental innovation is a minor change to an existing product, we would expect the probability of success in such an enterprise to be very high for the incumbent firm, which manufactures the existing product. From the entrant's perspective, the probability of success would not be as high, given that the entrant will attach wider interval spreads to its estimates of the efficacy of technologies in building a new product than will the incumbent in improving an existing one. In essence we are assuming the existence of some advantages of 'learning by doing'. Therefore, in the terms of our model we would expect p_1 to be high and p_2 to be lower than p_1.

Also, as the change in the product is not extensive, we would not expect this new product to cannibalise the old product significantly, therefore our cannibalisation

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variable, b, would be low[10]. If b were to be high then we would be considering a case of architectural innovation. The cost of attempting innovation would also not be particularly high given the nature of the innovation, thus c is also low. Therefore, in the case of incremental innovation with x remaining fixed at 100, we have three variables that are industry-specific, s, m and d.

We shall assume that d, the proportion of monopoly profit made in a duopoly scenario shall be 70%. This assumes therefore that there is some competition in a duopoly scenario but certainly not as severe as Bertrand competition. This therefore leaves us with two variables, s and m that will determine the outcome of the game.

Figure 6 : Who has the greater incentive? The case of incremental innovation.

S

M

M \ S	0.80	0.84	0.88	0.92	0.96	1.00	1.04	1.08	1.12	1.16	1.20	1.24	1.28	1.32	1.36	1.40	1.44	1.48	1.52	1.56	1.60	1.64	1.68	1.72	1.76	1.80
0.0%	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
4.0%	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
8.0%	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
12.0%	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
16.0%	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
20.0%	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
24.0%	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
28.0%	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	I	I
32.0%	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	I	I	I	I	I	I
36.0%	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	I	I	I	I	I	I	I	I	I
40.0%	E	E	E	E	E	E	E	E	E	E	E	E	E	E	I	I	I	I	I	I	I	I	I	I	I	I
44.0%	E	E	E	E	E	E	E	E	E	E	E	E	I	I	I	I	I	I	I	I	I	I	I	I	I	I
48.0%	E	E	E	E	E	E	E	E	E	E	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
52.0%	E	E	E	E	E	E	E	E	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
56.0%	E	E	E	E	E	E	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
60.0%	E	E	E	E	E	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
64.0%	E	E	E	E	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
68.0%	E	E	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
72.0%	E	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
76.0%	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
80.0%	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
84.0%	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
88.0%	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
92.0%	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
96.0%	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
100.0%	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I

10 Clearly any selection of these variables, without having a particular case in mind, will be arbitrary to some degree. We shall use p_1 = 90%, p_2 = 50% and b = 20% for this part of the analysis.

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Figure 6 shows when the respective players have the greater incentive to attempt incremental innovation, given the variables defined. Not all of these situations are necessarily feasible however. It is unlikely that the value of s will be less than 1 as this would indicate that the market for the new product is less lucrative than the old market. Given that this is an improvement to the product it would seem strange. It is also unlikely, given the fact that this is an incremental innovation, that the level of m, the market share of the incumbent in the event of a duopoly, will be less than 50%. If anything, a more sensible assumption would be that it is significantly higher than 50%. However, just with these very undemanding assumptions, we can see that the incumbent will nearly always have a greater incentive to innovate incrementally than the entrant.

It would be a grave mistake however to conclude from this that we would expect to see very few incremental innovations from entrants. Although the relative incentives offer some insight, yet more understanding can be obtained from looking at the outcomes of the game at these variables. Simply because one firm may have more incentive than another does not mean that one will attempt innovation whilst the other does not.

From Figure 7 it becomes clear that unless the market share of the incumbent in the new product market is very high, it is possible that the entrant will also attempt incremental innovation, even though it has less incentive to do so than the incumbent. Whether this will be the case will rely on the respective levels of m and s. This highlights the importance of not making general conclusions regarding innovation. In this situation it is highly uncertain whether the outcome of the game will be at node 1,2,3, or 4. All outcomes are possible. Therefore, the entrant may or may not attempt innovation according to the value of m, the market share of the incumbent in the event of a duopoly in the secondary product market. This could be considered to represent the strength of the brand of the incumbent. If it is too strong it acts as a disincentive to entrants to innovate. Also, the value of s, spillovers, will influence the decisions of either party. As s increases so does the incentive of each player to innovate.

Figure 7 : Game outcomes. The case of incremental innovation.

M \ S	0.80	0.84	0.88	0.92	0.96	1.00	1.04	1.08	1.12	1.16	1.20	1.24	1.28	1.32	1.36	1.40	1.44	1.48	1.52	1.56	1.60	1.64	1.68	1.72	1.76	1.80
0.0%	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	1	1	1	1	1	1	1	1	1
4.0%	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	1	1	1	1	1	1	1	1	1	1
8.0%	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	1	1	1	1	1	1	1	1	1	1	1
12.0%	3	3	3	3	3	3	3	3	3	3	3	3	3	3	1	1	1	1	1	1	1	1	1	1	1	1
16.0%	3	3	3	3	3	3	3	3	3	3	3	3	3	1	1	1	1	1	1	1	1	1	1	1	1	1
20.0%	3	3	3	3	3	3	3	3	3	3	3	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1
24.0%	3	3	3	3	3	3	3	3	3	3	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
28.0%	3	3	3	3	3	3	3	3	3	3	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
32.0%	3	3	3	3	3	3	3	3	3	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
36.0%	3	3	3	3	3	3	3	3	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
40.0%	4	3	3	3	3	3	3	3	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
44.0%	4	4	4	3	3	3	3	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
48.0%	4	4	4	4	3	3	3	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
52.0%	4	4	4	4	4	3	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
56.0%	4	4	4	4	4	4	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
60.0%	4	4	4	4	4	4	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
64.0%	4	4	4	4	4	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
68.0%	4	4	4	4	4	2	2	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1
72.0%	4	4	4	4	4	2	2	2	2	2	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1
76.0%	4	4	4	4	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1	1	1	1	1	1
80.0%	4	4	4	4	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1
84.0%	4	4	4	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
88.0%	4	4	4	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
92.0%	4	4	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
96.0%	4	4	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
100.0%	4	4	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2

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Radical Innovation

The second type of innovation we shall discuss is radical innovation. This is defined as a new product that significantly cannibalises the original product market. Such a type of innovation would be characterised by different levels of variables than incremental innovation. There is no *a priori* reason to assume that an incumbent would have an advantage in research and development of this type. Thus we shall hold p_1 and p_2 to be equal to each other. Also, we would expect the levels of p_1 and p_2 to be low as it is a significant innovation. Conversely, we would expect the level of b

to be high for the same reason.[11] Once again we shall arbitrarily set d to be 70%. The cost of innovation, c, will be slightly higher than in the case of incremental innovation.

Thus, once again we are left with two industry-specific variables, s and m. The effects of these variables on the incentives for radical innovation can be seen in Figure 8. Clearly in all situations, given these variables, the entrant has a greater incentive to innovate than the incumbent does. There are no levels of s and m that give the incumbent firm a greater incentive to innovate than the entrant. Is this then evidence for the existence of the incumbent's curse? Certainly there will be no circumstances in which the incumbent has an incentive to innovate and the entrant does not. But to fully understand the factors behind a drastic innovation we must once again look at the outcome of the game in this situation.

The outcome of the game in the same situation as above can be seen in Figure 8. From this it is clear that, although the entrant will always have more incentive to innovate, there are many situations in which the Nash equilibrium is at Node 1 rather than Node 3, that is to say, both firms attempt innovation. Indeed, we can see from Figure 9 that the outcome of the game is sensitive to the level of s rather than the level of m. Therefore we can conclude that if the level of spillovers is high enough then both the entrant and the incumbent will attempt innovation. That is to say, the incumbent's curse is only valid if spillovers are low.

11 Once again we shall choose arbitrary levels for these variables. We shall use $p_1 = p_2 = 20\%$ and $b = 90\%$ for this part of the analysis.

Figure 8: Who has the most incentive? The case of drastic innovation

S

M

	0.80	0.84	0.88	0.92	0.96	1.00	1.04	1.08	1.12	1.16	1.20	1.24	1.28	1.32	1.36	1.40	1.44	1.48	1.52	1.56	1.60	1.64	1.68	1.72	1.76	1.80
0.0%	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
4.0%	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
8.0%	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
12.0%	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
16.0%	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
20.0%	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
24.0%	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
28.0%	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
32.0%	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
36.0%	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
40.0%	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
44.0%	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
48.0%	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
52.0%	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
56.0%	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
60.0%	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
64.0%	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
68.0%	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
72.0%	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
76.0%	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
80.0%	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
84.0%	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
88.0%	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
92.0%	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
96.0%	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
100.0%	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E

Figure 9: Game outcomes. The case of drastic innovation.

S

M

	0.80	0.84	0.88	0.92	0.96	1.00	1.04	1.08	1.12	1.16	1.20	1.24	1.28	1.32	1.36	1.40	1.44	1.48	1.52	1.56	1.60	1.64	1.68	1.72	1.76	1.80
0.0%	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	1	1	1	1	1	1	1	1	1	1
4.0%	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	1	1	1	1	1	1	1	1	1	1
8.0%	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	1	1	1	1	1	1	1	1	1	1	1
12.0%	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	1	1	1	1	1	1	1	1	1	1	1
16.0%	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	1	1	1	1	1	1	1	1	1	1	1
20.0%	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	1	1	1	1	1	1	1	1	1	1	1
24.0%	3	3	3	3	3	3	3	3	3	3	3	3	3	3	1	1	1	1	1	1	1	1	1	1	1	1
28.0%	3	3	3	3	3	3	3	3	3	3	3	3	3	3	1	1	1	1	1	1	1	1	1	1	1	1
32.0%	3	3	3	3	3	3	3	3	3	3	3	3	3	3	1	1	1	1	1	1	1	1	1	1	1	1
36.0%	3	3	3	3	3	3	3	3	3	3	3	3	3	3	1	1	1	1	1	1	1	1	1	1	1	1
40.0%	3	3	3	3	3	3	3	3	3	3	3	3	3	3	1	1	1	1	1	1	1	1	1	1	1	1
44.0%	3	3	3	3	3	3	3	3	3	3	3	3	3	1	1	1	1	1	1	1	1	1	1	1	1	1
48.0%	3	3	3	3	3	3	3	3	3	3	3	3	3	1	1	1	1	1	1	1	1	1	1	1	1	1
52.0%	3	3	3	3	3	3	3	3	3	3	3	3	3	1	1	1	1	1	1	1	1	1	1	1	1	1
56.0%	3	3	3	3	3	3	3	3	3	3	3	3	3	1	1	1	1	1	1	1	1	1	1	1	1	1
60.0%	3	3	3	3	3	3	3	3	3	3	3	3	3	1	1	1	1	1	1	1	1	1	1	1	1	1
64.0%	3	3	3	3	3	3	3	3	3	3	3	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1
68.0%	3	3	3	3	3	3	3	3	3	3	3	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1
72.0%	3	3	3	3	3	3	3	3	3	3	3	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1
76.0%	3	3	3	3	3	3	3	3	3	3	3	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1
80.0%	3	3	3	3	3	3	3	3	3	3	3	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1
84.0%	3	3	3	3	3	3	3	3	3	3	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
88.0%	3	3	3	3	3	3	3	3	3	3	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
92.0%	3	3	3	3	3	3	3	3	3	3	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
96.0%	3	3	3	3	3	3	3	3	3	3	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
100.0%	3	3	3	3	3	3	3	3	3	3	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

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We must ensure that this result holds for a greater range of scenarios than the arbitrary one we have just examined. If we examine the impact of the level of spillovers on the incumbent's curse over a range of values of p and b then we shall obtain a clearer conclusion as to the validity of this result.

The incumbent's curse has been defined as a scenario in which the entrant attempts innovation and the incumbent does not. We have seen that this occurrence is sensitive to the level of spillovers. Figures 10 and 11 show the level of spillovers against the levels of p and b, which may be regarded as a measure of the degree that the innovation is drastic. The more drastic the innovation the higher we might expect the level of b and the lower the level of p. Therefore, from looking at the impact of spillovers over a range of these values, it is clear that the incumbent's curse is very much subject to the level of spillovers. Indeed, if spillovers are high, there is only a very small range of drastic innovations in which the incumbent's curse will occur.

Figure 10: Game outcomes for levels of spillovers and cannibalisation where *p*=20%

S

B	0.80	0.84	0.88	0.92	0.96	1.00	1.04	1.08	1.12	1.16	1.20	1.24	1.28	1.32	1.36	1.40	1.44	1.48	1.52	1.56	1.60	1.64	1.68	1.72	1.76	1.80
0.0%	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
5.0%	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
10.0%	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
15.0%	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
20.0%	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	3
25.0%	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	3	3	3	3	3	3	3	3	3	3
30.0%	4	4	4	4	4	4	4	4	4	4	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
35.0%	4	4	4	4	4	4	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
40.0%	4	4	4	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	1	1
45.0%	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	1	1	1	1	1
50.0%	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	1	1	1	1	1	1	1
55.0%	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	1	1	1	1	1	1	1	1
60.0%	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	1	1	1	1	1	1	1	1	1
65.0%	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	1	1	1	1	1	1	1	1	1	1
70.0%	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	1	1	1	1	1	1	1	1	1	1	1
75.0%	3	3	3	3	3	3	3	3	3	3	3	3	3	3	1	1	1	1	1	1	1	1	1	1	1	1
80.0%	3	3	3	3	3	3	3	3	3	3	3	3	3	1	1	1	1	1	1	1	1	1	1	1	1	1
85.0%	3	3	3	3	3	3	3	3	3	3	3	3	3	1	1	1	1	1	1	1	1	1	1	1	1	1
90.0%	3	3	3	3	3	3	3	3	3	3	3	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1
95.0%	3	3	3	3	3	3	3	3	3	3	3	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1
100.0%	3	3	3	3	3	3	3	3	3	3	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

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Figure 11: Game outcomes for levels of spillovers and *p* where *b*=60%

S

P	0.80	0.84	0.88	0.92	0.96	1.00	1.04	1.08	1.12	1.16	1.20	1.24	1.28	1.32	1.36	1.40	1.44	1.48	1.52	1.56	1.60	1.64	1.68	1.72	1.76	1.80
0.0%	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
5.0%	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
10.0%	4	4	4	4	4	4	4	4	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
15.0%	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	1	1	1	1
20.0%	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	1	1	1	1	1	1	1	1	1
25.0%	3	3	3	3	3	3	3	3	3	3	3	3	3	1	1	1	1	1	1	1	1	1	1	1	1	1
30.0%	3	3	3	3	3	3	3	3	3	3	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
35.0%	3	3	3	3	3	3	3	3	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
40.0%	3	3	3	3	3	3	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
45.0%	3	3	3	3	3	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
50.0%	3	3	3	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
55.0%	3	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
60.0%	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
65.0%	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
70.0%	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
75.0%	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
80.0%	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
85.0%	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
90.0%	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
95.0%	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
100.0%	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Obviously, the data shown in Figures 10 and 11 are subject to the respective fixed levels of p and b chosen. In Figure 10 we can see that as b increases then less spillovers are required for the incumbent to attempt innovation, i.e. Node 1 becomes the Nash equilibrium at lower levels of s. In Figure 11, we can see that as p increases the lower the levels of spillovers are required for the incumbent to attempt innovation. This is not unexpected, as the chances of success increase and as the cannibalisation of the old market increases, one would expect the incumbent to attempt innovation. The key conclusion that may be drawn from this analysis is that, for drastic innovations, the incumbent's curse is only valid under a limited range of situations. The respective levels of both p and b define those situations and the range of these situations reduces as the level of spillovers increases.

Therefore returning to the earlier section regarding the significance of the no spillovers assumption we can see that not only is a model sensitive to such an assumption but that spillovers can drive the entire argument against the existence of the incumbent's curse. Namely, if spillovers are high enough then the incumbent will attempt innovation, regardless of the levels of the other variables.

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We are not concluding here that the incumbent's curse does not exist, nor that an incumbent disinclination to innovate does. The aim of this paper was to reconcile the respective schools of thought and to gain an insight as to why two such different conclusions can be reached. The answer is clear. First, the incumbent's curse, if it does exist, only does so for drastic innovations. Secondly, it only exists in a range of scenarios. Therefore, it is no surprise that some industries should exhibit evidence of an incumbent's curse whilst others may not. Equally important is the point that observed evidence of innovation should not be translated into a conclusion on innovation incentives. One could observe a series of entrants making drastic innovations that would still be totally consistent with the notion that there is no incumbent's curse in that industry. This is because of the stochastic innovation process that allows for the possibility of a failed attempt by the incumbent. This is an advantage of the model over a deterministic model of innovation.

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Conclusion

This paper set out to investigate those factors that drive innovation in industries. It did not set out to examine a particular industry nor did it seek to obtain a generalised result regarding the effect of market structure on innovation. It therefore comes as no surprise that in a project that sought to escape the restrictions placed by assumptions a model, the result is highly equivocal. That is to say, we cannot make a blanket statement with regard to the existence or otherwise of an Incumbent's Curse. In a sense, that is precisely what this paper set out to achieve. As discussed at the beginning of the investigation, the fact that there is a controversy over the notion, with both sides producing examples of industries as evidence indicates that it would be wrong to attempt to reach a definitive conclusion. The philosophical angle of this investigation was to allow as much flexibility as possible in the model. This has led us to develop a model of innovation that, within the constraints we placed upon the exercise, allows us to look at a range of scenarios and determine what are the factors that cause different innovation profiles in different industries. The result of this investigation was that, in the case of drastic innovation, the main driving factor behind whether an industry exhibited an Incumbent's Curse was the level of spillovers.

Some further interesting conclusions to be drawn from this paper relate to the strength of the assumptions regarding common knowledge and rationality. The paper began by building a very simple model of product innovation which contained a number of severely restricting assumptions on the environment in which the game took place. However, when we removed all of these assumptions and replaced them with variables, we found that the same result occurred. That is, Node 2 was not possible as a Nash Equilibrium. This result only disappeared when the assumptions regarding common knowledge and mutual knowledge of rationality were removed. It was only then that we were able to conduct an investigation into the sensitivity of the game to the respective variables.

The further result of this investigation is that it has now set up an opportunity for further detailed research into a dynamic model of innovation using conditional probabilities. The fact that most of the variables, as defined in this paper, show little or no significance to the derivation of the Nash equilibria means that under a dynamic framework we can now ask to what extent an attempt at innovation is a signal to the level of spillovers. An incumbent firm, even if facing an incentive to attempt innovation must consider whether, in so doing, it is signalling to an entrant that spillovers are high and that they should also be attempting innovation.

Perhaps the key result of this paper has been the demonstration of the power of assumptions typically made in game theoretic models. Sutton's point that the model can be set up in many ways is valid. But to some extent this is resolved when case-specific models are developed. Such a model should be set up to reflect the situation it attempts to replicate, something a general model cannot do. But beyond this there are assumptions made in the way the Nash equilibria within these models are reached. It is these that this paper has shown to be at least as significant as the way in which the model is set up.

It is too easy for models, especially those which seek to explain a historical case, to start backwards from the result. That is to say, if the model must explain an occurrence of entrant innovation then the temptation to introduce assumptions that simplify the mathematical features of the model is significant. Certainly when these assumptions lead the model to a conclusion in line with the case study it seeks to explain, there is a temptation to ignore the fact that such assumptions could be driving the result of the model. This paper has demonstrated these dangers and has, by attempting to avoid these same traps, concluded that the level of spillovers is a major driver for innovation in a static framework. This has therefore opened a path into investigation of a dynamic framework in which the signalling effects of innovation attempts may be taken into account.

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Appendix

	A	B	C	D	E	F	G
1	=IF(K2<=0,1,0)	=IF(C1=TRUE,1,0)	TRUE				
2	=IF(J1>L1,1,0)	0.04					
3	=IF(I2>0,1,0)	=INDEX(IL4:IL104,IL1)	=IF(AZ2=0,INDEX(IM4:IM104,IM1),"")	=INDEX($IN$4:$IN$104,$IN$1)	=INDEX(IO4:IO104,IO1)	=INDEX(IP4:IP74,IP1)	=INDEX(IQ4:IQ104,IQ1)
4	=IF(I1>K1,1,0)						
5	=IF(K1>J1,1,0)				=IF(AZ2=0,"P1","P")		=IF(AZ2=0,"P2","")
6	=IF(I1>L1,1,0)						
7	=IF(J1>L1,1,0.5)	=B3					
8	=IF(K1<I1,1,0.5)	0.025		=IF(AZ2=0,"P1","P")	=IF(B1=1,F8,G8)	=0.04	=0.025
9	=A7*A8	=IF(B1=1,B2,B8)					
10	=IF(A1=1,A11,IF(A3=1, A12, IF(A5=1,3,IF(A6=1,2,IF(A9=1,2,IF(A9=0.25,3,5))))))	B					
11	=IF(A2=1,2,4)	=I3					
12	=IF(A4=1,1,3)						
13		=IF(MIN(W6,X6)>=MIN(Y6,Z6),1,0)					
14		=IF(MIN(W7,Y7)>=MIN(X7,Z7),1,0)					
15		=IF(AM4=1,IF(A10=1,O1,IF(A10=2,O1, IF(A10=3,N1,IF(A10=4,N1,M1)))),IF(B13=1,O1,N1))					
16		=IF(AN4=1,IF(A10=1,O1,IF(A10=2,N1, IF(A10=3,O1,IF(A10=4,N1,M1)))),IF(B14=1,O1,N1))					
17		=IF(B15="I",IF(B16="I",1,IF(B16="N",2,"M")), IF(B15="N",IF(B16="I",3,IF(B16="N",4,"M")),"M"))					

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	H	I	J	K	L	M	N	O	P
1	=(1-I3)*F3	=IF(AZ2=0,((B3*C3*E3*H3*G3*F3*I3)-(B3*C3*D3)+(B3*C3*H1)+(B3*(1-C3)*((I3*E3*F3)-D3+H1))+(C3*(1-B3)*(-D3+H1))+((1-B3)*(1-C3)*(F3-D3))), ((B3*B3*E3*H3*G3*F3*I3)-(B3*B3*D3)+(B3*B3*H1)+(B3*(1-B3)*((I3*E3*F3)-D3+H1))+(B3*(1-B3)*(-D3+H1))+((1-B3)*(1-B3)*(F3-D3))))	=((B3*E3*I3*F3)-(B3*F3)+(B3*H1)+F3-D3)	=IF(AZ2=0,((F3-(F3*C3))+(C3*H1)),((F3-(F3*B3))+(B3*H1)))	=F3	M	N	I	1
2		=IF(AZ2=0,((B3*C3*E3*(1-H3)*G3*F3*I3)-(B3*C3*D3)+(B3*(1-C3)*(-D3))+(C3*(1-B3)*((E3*F3*I3)-D3))+((1-B3)*(1-C3)*(-D3))), ((B3*B3*E3*(1-H3)*G3*F3*I3)-(B3*B3*D3)+(B3*(1-B3)*(-D3))+(B3*(1-B3)*((E3*F3*I3)-D3))+((1-B3)*(1-B3)*(-D3))))	=0	=IF(AZ2=0,((C3*I3*F3*E3)-D3) ,((B3*I3*F3*E3)-D3))	=0				
3	=INDEX(IR4:IR104,IR1)	=INDEX(IS4:IS104,IS1)							
4									
5		C		S		X		D	
6									
7									
8	Node table								(Press F9 to calculate)
9									
10									
11									
12									
13									
14									
15									
16									
17									

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	Q	R	S	T	U	V	W	X	Y
1	2	3	4			=IF(B17="M", "I Choose I for ","")	=IF(B17="M",X1,"")	=(-K2/(I2-K2))	=IF((I1-J1-K1+L1)<0,0,((L1-J1)/(I1-J1-K1+L1)))
2						=IF(B17="M", "E Choose I for ","")	=IF(B17="M",Y1,"")	=(1-X1)	=(1-Y1)
3							=IF(B17="M","Mixed strategies played","")		
4							=IF($B$17=1,"!",IF($B$17="M",(X1*Y1),""))	=IF(B17=2,"!",IF(B17="M",(X1*Y2),""))	=IF(B17=3,"!",IF(B17="M",(X2*Y1),""))
5	M		B			Node	1	2	3
6						Incumbent	=I1	=J1	=K1
7						Entrant	=I2	=J2	=K2
8									
9									
10									
11									
12									
13									
14									
15									
16									
17									

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	Z	AA	AB	AC	AM	AN	AZ
1	=((X1*Y1*I1)+(X1*Y2*J1)+(X2*Y1*K1)+(X2*Y2*L1))				Rational Play	Rational Play	TRUE
2	=((X1*Y1*I2)+(X1*Y2*J2)+(X2*Y1*K2)+(X2*Y2*L2))				Maximin	Maximin	=IF(AZ1=FALSE,0,1)
3							
4	=IF(B17=4,"I",IF(B17="M",(X2*Y2),""))				2	2	
5	4						
6	=L1	=IF(B17="M","E(I)=","")	=IF(B17="M",Z1,"")				
7	=L2	=IF(B17="M","E(E)=","")	=IF(B17="M",Z2,"")				
8							
9							
10							
11							
12							
13							
14							
15							
16							
17							

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